Metocean forecasting for ports and terminals

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Abstract

Industry standard numerical models are excellent and accurate tools for analysis of port plans and design. They link meteorological and oceanographic information to impacts on moored vessels and thereby provide the metocean conditions along the berths. By use of relevant motion and safety criteria for moored vessels, numerical modelling studies can assist the designer and the port owner to determine the optimal protection for the port operation.

Operators and users of an exposed port or terminal will from time to time experience downtime due to adverse weather conditions. Downtime can be associated with strong currents in the approach channel and port entrance or with difficulties encountered for pilot assistance. It can also be due to excessive motions of the vessel resulting in suspension of loading/unloading by cranes or over ramps.

If the port operator and the port user receive early information on conditions in and around the port and is able to interpret this information into expected conditions for arriving vessels they will be able to make prudent decisions on optimal and safe arrival at the port.

This paper describes the use of numerical models and state-of-art-methods for ship motion analysis in combination with metocean forecast to build a web-based operational tool for vessels calling at ports and, terminal facilities. The systems present in a user friendly way the forecast exposure at the berths for the coming week which can guide the port operator to select the most suitable time for arrival and berthing and selecting the optimal berth for the planned loading/unloading operation.

Keywords: Port of Hanstholm, water forecast, wave disturbance, DSS,

1. Introduction

The primary objective of port engineers is to create safe and efficient harbour infrastructures. The design process involves technical disciplines and interaction with future users in order to define the requirements from the user's perspective. During the planning and design process decisions have to be made on more or less firm basis and since we are operating under non-stationary conditions we need to make decisions based on compromises between costs and benefits. Consequently even in the best port, the user will be required to make decisions that include assessments related to issues that were fundamental in the design process.

The question we ask ourselves is then:
Can the detailed knowledge and the refined methods we use for design of ports also help the users in making even better decisions relating to operation of the port and its infrastructures?

2. Objectives and system architecture

The basic assumption is that reduction or elimination of uncertainties will lead to better decisions during daily operation of the port. Better decisions in this context means reducing risks for personnel and structures and increasing efficiency of operations.

DHI has developed a decision support system (DSS) for the Danish Port of Hanstholm. The system is built on a combination of numerical modeling tools which have been used for planning and design studies as well as for forecast . A general forecast system for the aquatic environment, see www.waterforecast.com, has been in operation for the Danish waters since 2001 and specific forecast services have been established for a number of construction projects, for ferry routes and for oil spill services. Common for all these applications is the use of DHI's numerical models for hydrodynamics and waves, known as the MIKE family of models.

We anticipate that the primary users of a decision support system will be the harbour master and the vessels calling the port. The users can benefit from information in various sectors of the port:

- Port entrance and approach area: Prediction of water depths, currents and waves
- Berths and terminals: Prediction of wave conditions
- Dedicated ships: Prediction of mooring loads and ship movements

This type of information can be seen as an extension of general Vessel Traffic Information Systems and Vessel Arrival Systems.

The overall architecture of the system comprise:

- Weather forecast
- Tidal forecast
- Wave and current forecast model for nearshore conditions in front of the port entrance

- Transformation module relating conditions inside the port (along the berths) to the outside conditions
- User interface and event manager

The points and parameters of interest will be specific for each port and they depend a.o. on the types and size of ships and commodities. Also loading and unloading equipment shall be considered where these are critical elements defining downtime of operations.

3. Port of Hanstholm

Port of Hanstholm is the most recent port built on the open coast facing the North Sea in Denmark. The port was established to serve the fishing industry and to be a basis for regional development (Lundgren, 1962). The port was inaugurated in 1967 after intense studies of sediment transport and constructability had been performed. The port is protected by two caisson breakwaters and the 145m wide entrance has a water depth of 9m. Today the port is the largest Danish consumer fishing port with an annual turnover of more than 75 million EUR. It furthermore is an important link for ferry transports to Iceland and Faroe Islands. The port handles more than 500 thousand tons of goods every year by ferries and other cargo vessels.

Fig. 1 Location of the Port of Hanstholm on the northwestern coast of Denmark

The wave climate at Hanstholm is harsh with winter storms of more than 5m significant wave height and East-going currents running up to 2m/s in front of the port (Juhl, 1994). The envisaged sedimentation problem related to annual longshore transport of more then 1 mill m^3 of sand has been kept well under control by the original breakwater layout and amounts to a local deposition of about 5% (Jensen, 2005). During the most severe storm conditions downtime of loading and unloading is experienced for the ferries and for fishing vessels at the auction quay.

4. Model description

4.1 Background information

Numerical models of currents and waves have been used repeatedly to assess the minor changes of port structures during the years. Recently such models have been used as part of a major expansion study for the port.

This paper describes how these models can be integrated for operational purposes in the port.

Traditionally, arriving and departing vessels in Hanstholm receive information on actual wave and current conditions by radio communication. Pilot assistance is recommended for vessels unfamiliar with the port.

The objective is now to create a 'water forecast' which aims at predicting the local conditions in and around the port for a window of up to 5 days, whereby informed decisions about arrival time at the port can be made well in advance.

A regional full 3D hydrodynamic model covering the North Sea and Baltic Sea is established by DHI as a general water forecast tool for Danish waters. This model is forced by tidal predictions and by wind fields obtained from a global or regional meteorological model. Together with a spectral wave model for the same area the model is available as a Water Forecast service providing a large number of parameters such as waves, currents, salinity and water quality properties.

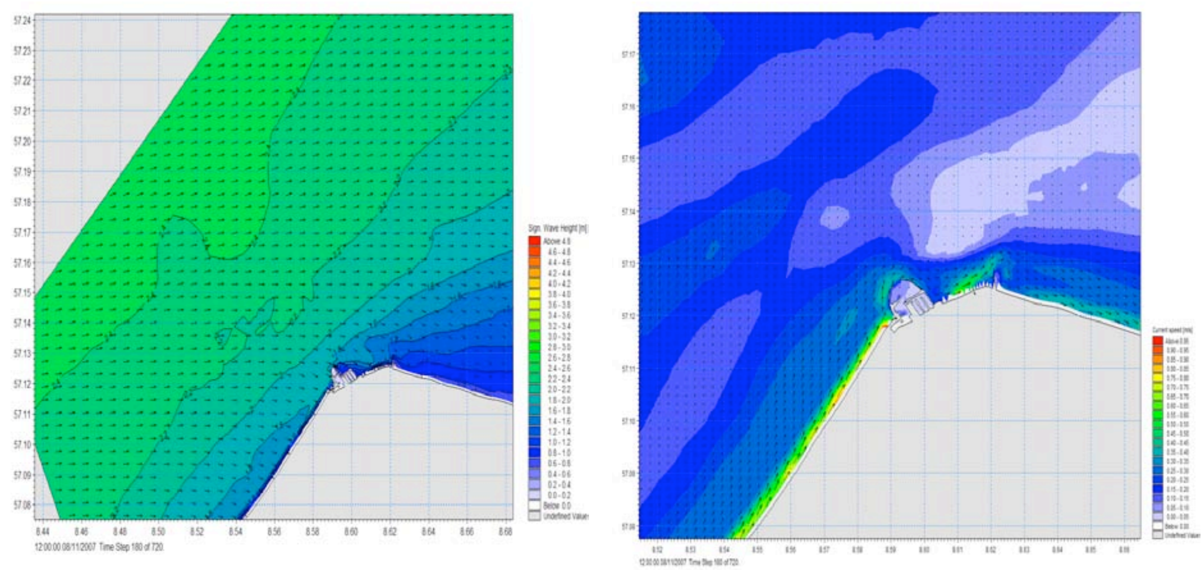

Fig.2 Wave conditions and current conditions around the Hanstholm headland. Note the strong north-east going littoral current

Local models around the site of interest transform and detail the waves and current conditions to be expected in the forecast period. The tools we use are the MIKE 21 suite of models (Sørensen, 2004) that compute the local hydrodynamics – currents and water levels – and the spectral wave model computes the wave field around the port as shown in Figure 3.

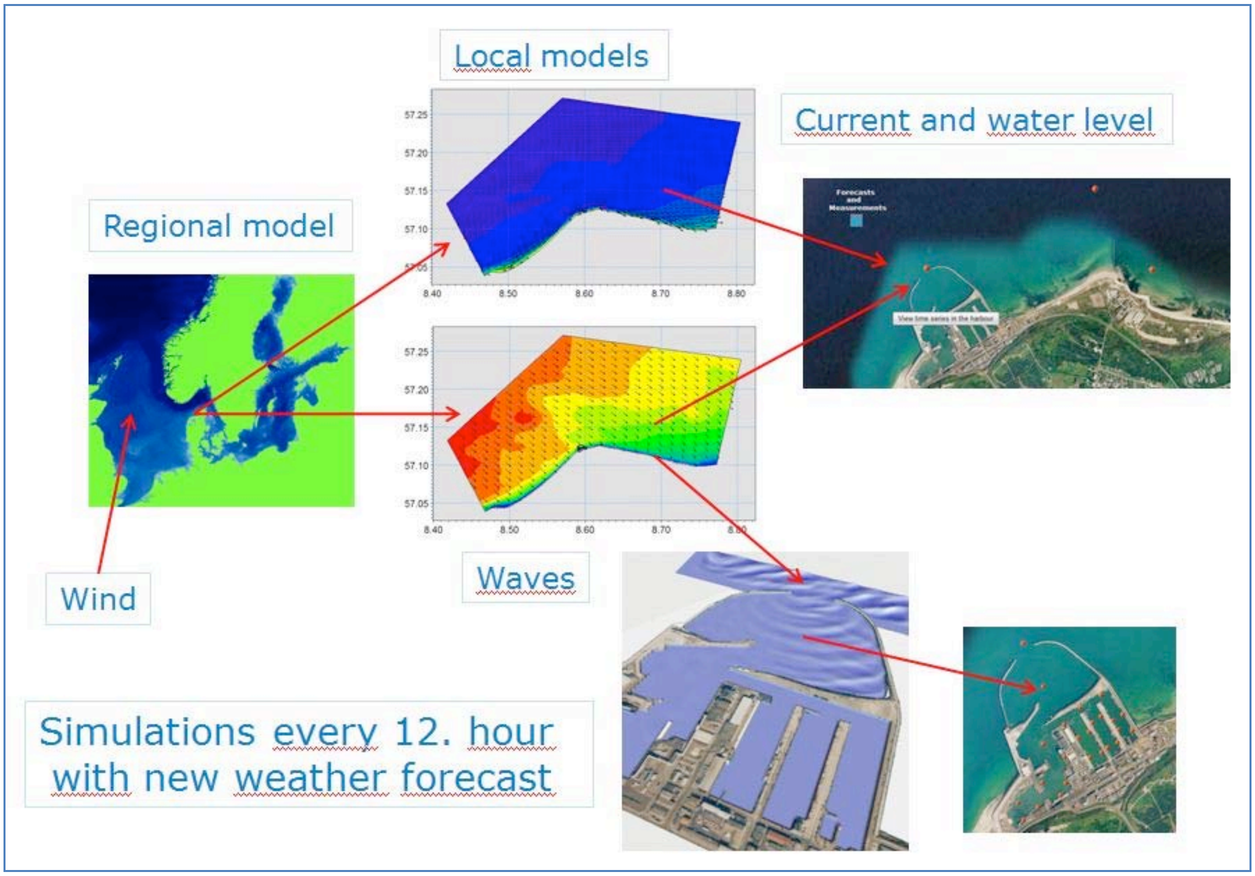

Fig 3. Water forecast modelling sequence

As part of the set-up of the forecast the model results are compared with measurement data to ensure the correctness of data. In the present case actual wind fields were used to hindcast wave conditions. Comparison of these hindcast waves with data from the permanent wave recorder at Hanstholm is shown in Fig. 4

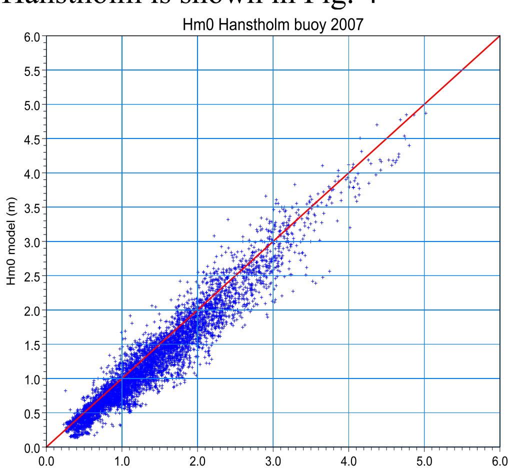

Fig. 4. Verification of hindcast against measured waves at Hanstholm

4.2 Impact on port operations (local models)

Conditions in port entrance and approach channel

The currents and waves in front of the port entrance are critical parameters for safe arrival and departure of vessels. Relevant information is readily available from the local models as described above. In ports with dredged access channels it may be relevant to add other features linking predicted position on the track of the vessel to the variable tide levels, currents and waves during the transit of the channel.

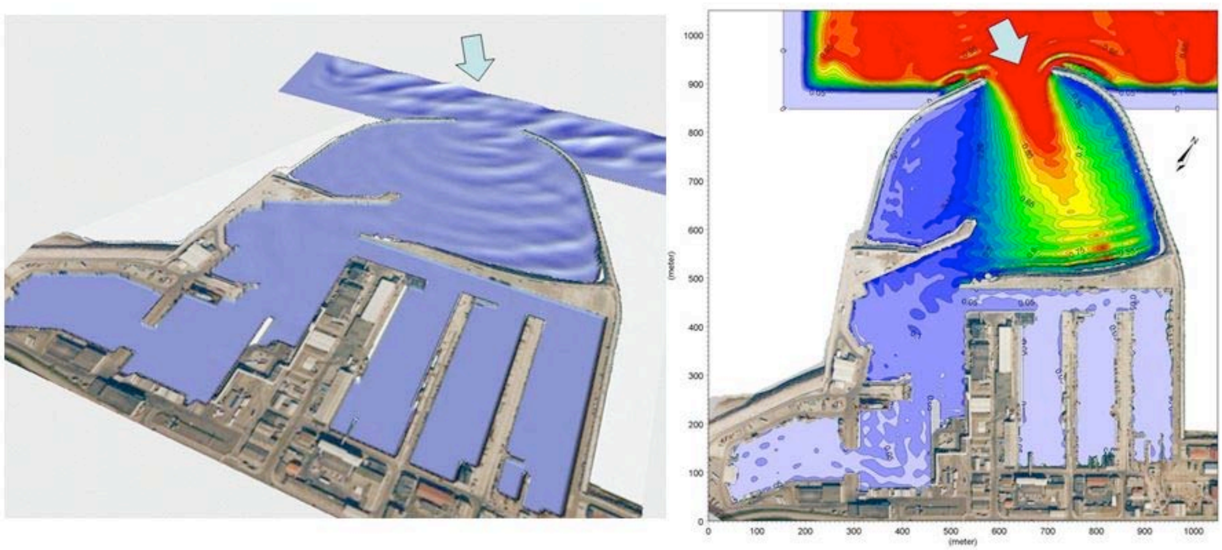

Fig 5 Modelling of wave conditions in the port by Boussinesq model. The isoline plot shows the wave height coefficients in the entire port.

Conditions along the berths

Detailed wave conditions inside the port are computed by the time domain Boussinesq wave model (MIKE 21 BW) (Christensen, 2008). This model computes the time history of waves in the entire computational domain with a grid size of 3m. Ideally this computation should be done concurrently, but the computational demands make this impossible at this point in time. Consequently we adopt another strategy by using a library of conditions which link wave conditions at the port entrance to wave conditions inside the port. The details of this library – the wave agitation database – are such that for a specific wave condition at the port entrance (wave height, period and direction) the condition at any point inside the port can be extracted. To build the database 50 scenarios have been calculated to cover a matrix of 5 different periods and 10 different directions.

The forecasts inside the harbour are obtained by interpolation from the Boussinesq wave model scenario runs. According to the wave conditions at the entrance (wave direction and wave period), a coefficient is selected and multiplied by the wave height at the entrance to give the wave height inside the harbour, at the different locations. This principle is described in Figure 6.

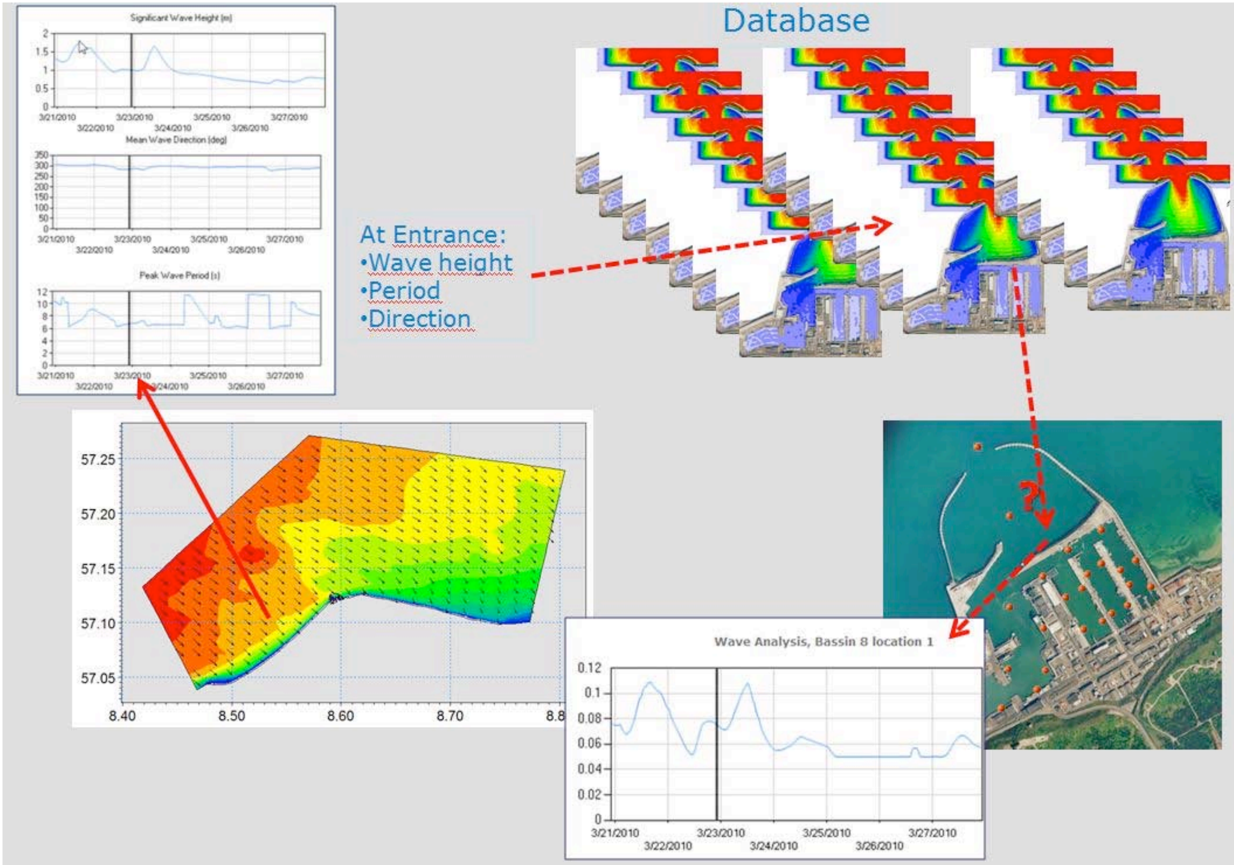

Fig 6 Prediction of wave conditions at a location in the port.

4.3 Ship motions

It is realized by port professionals that a wave description along a berth is not a very precise measure for conditions for moored vessels. Other parameters than wave heights govern the ship motions which are responsible for the operational constraints for loading and unloading of goods. To cope with this researchers and practitioners have attempted to establish criteria for tolerable vessel motions for different types of ships and handling of goods. Within PIANC working groups have been established to define criteria (PIANC, 1995). Recently PIANC working group 52 was created with the objective of defining criteria for loading and unloading containers.

In order to make better use of ship motion criteria it is necessary to determine the link between actual wave conditions at a berth and the imposed ship motions. This is a complex problem which in the real world involves the geometry of the port and the actual mooring practice for the ship.

For dedicated berths, e.g. container terminals or ferry berths, where high productivity and fast turn-around are key requirements, it is possible to predict ship motions of typical vessels moored with standard equipment. The predicted vessel motions can then be used instead of wave heights in the forecast system and thereby provide a more precise estimate of the potential precautions to be implemented or down-time to predicted.

5. The Port Decision Support System

The system applies web technologies for data communication and it includes an event manager tool which sends alerts to users.

The Port DSS provides 5-day forecasts with updates every 12 hours. The results are published as time series plots and animation maps.

The dashboard entry page on the web-site, Figure 7, shows a navigation bar through which it is possible to call the different results. Under the tab 'Time Series' it is possible to obtain the following data:

- Wind data
- Forecasts and measurements at the reference position outside the port
- Forecast conditions at selected points in- and outside the port

The tab 'Animations' gives access to 2D animation maps of the local model area.

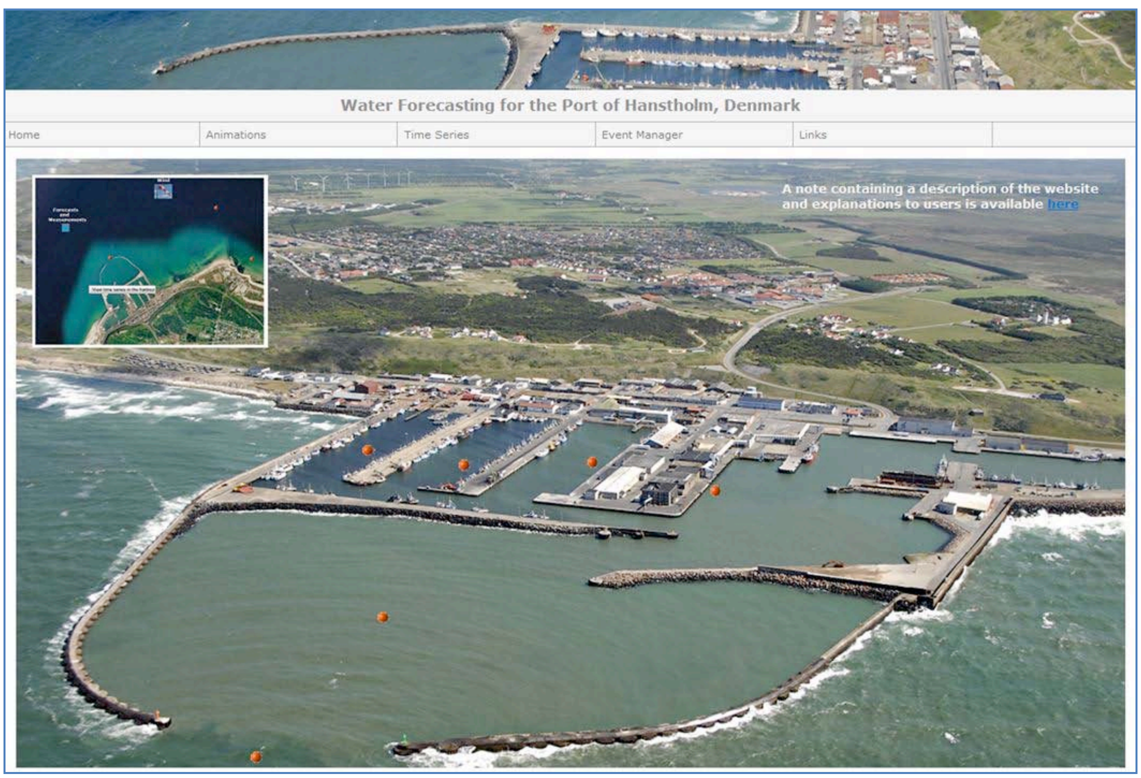

Fig. 7 Dashboard entry page with the navigation bar

5.1 Time Series

Locations which can be selected by the user are shown as red dots on the map. A click on one of these dots open the time series related to this location.

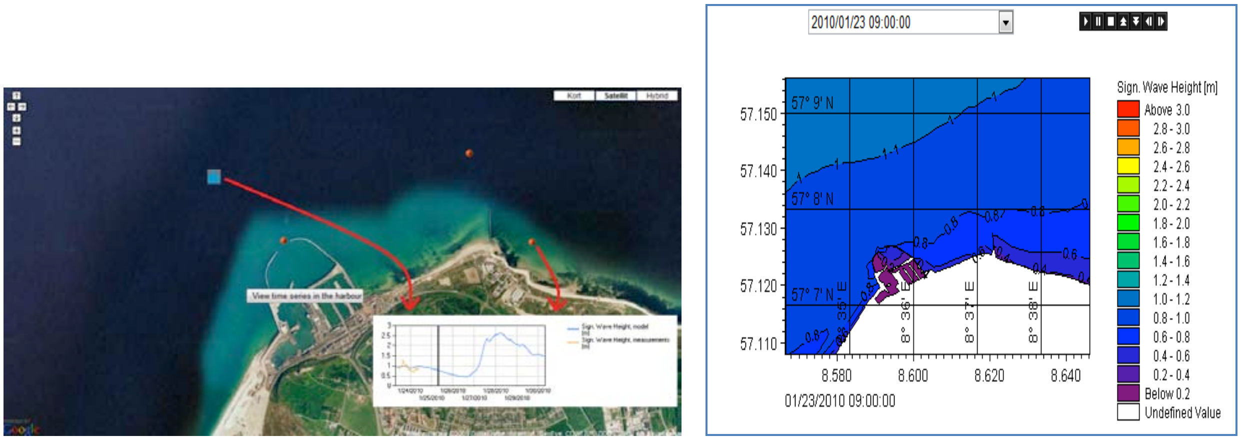

Fig 8 Time series of forecast and animated maps can be accessed from the navigation bar.

5.2 Event Manager

The Event Manager is a tool sending alerts (by emails and/or SMSs) to users when the predicted values reached by a parameter exceed a prescribed value. In order to use this feature, the threshold values must be entered in the table. This is done through a three steps procedure:

1. Registration/Login. When registered, users can access the event table and set thresholds in the boxes.

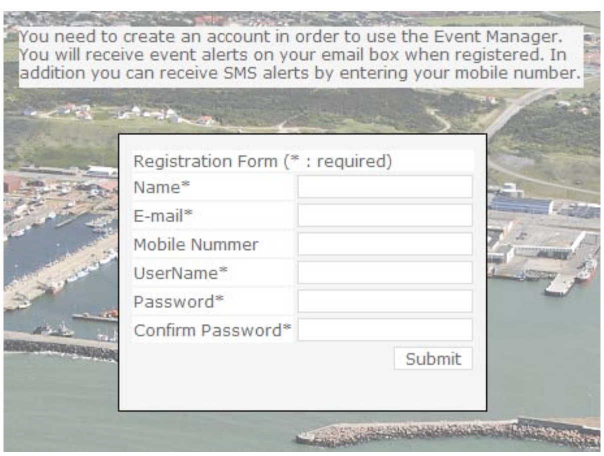

Fig. 9 Registration form

2. Setting threshold values: a maximum of three parameters can be entered in the event table.

3. Save changes. After initialization or modifications, the values are sent to the system by clicking on “Save”.

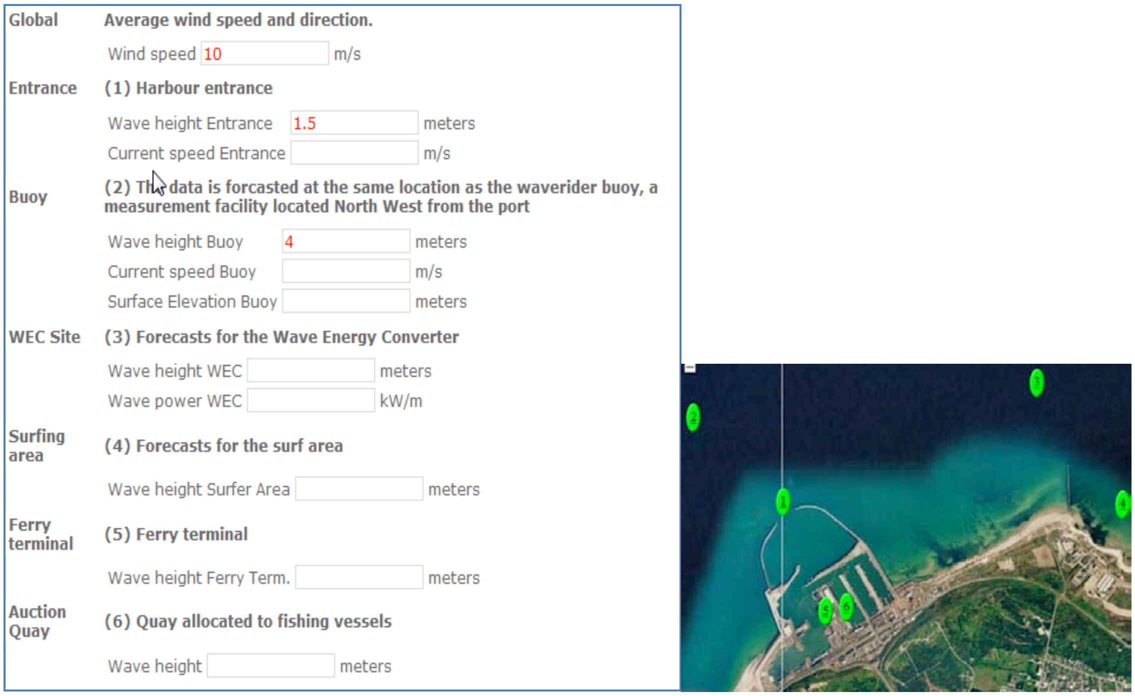

Fig.10 Event table and location reference

6. User applications and benefits

The system has been created for port operations as the main target group. We envisage that the users will be port captains, pilots and mariners as well as terminal operators. With little extra effort it will also be possible to file incidence reports about critical events and related metocean data. Such a facility will be useful for the port authorities to collect information for subsequent analysis and building operational experience.

As shown in the event table above other parties may also be potential users of nearshore metocean conditions forecast. In Hanstholm there is a wave power test site. The users here need to take special precautions in the case of extreme wave conditions where the power devices need to be adjusted to a stand-by mode.

An example for leisure and sports is the surfer community along the same coast. The system will help these users to plan their trips to the coast for the best possible experience.

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